

# Applications of Water Vapor-derived Multispectral Composites for Geostationary Satellites

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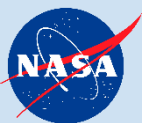
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Kevin Fuell – University of Alabama in Huntsville

Frank LaFontaine – Jacobs Technology

Nicholas Elmer – NASA Postdoctoral Program

Keywords: RGB composite imagery, vertical distribution of moisture



# Motivation



Rich data sources of geostationary multispectral imagery to look at unique spatial and temporal variations in water vapor which can play an important role in the development of high impact weather events

Multispectral image data provides Red-Green-Blue (RGB) composite products which qualitatively portray different aspects of atmospheric moisture variation

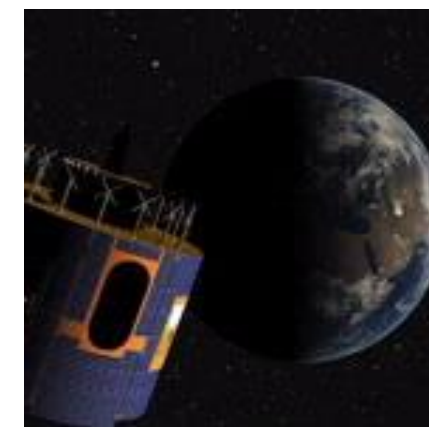


Himawari

Need to better understand the complementary nature of these products to diagnose important aspects of weather systems



GOES\_R

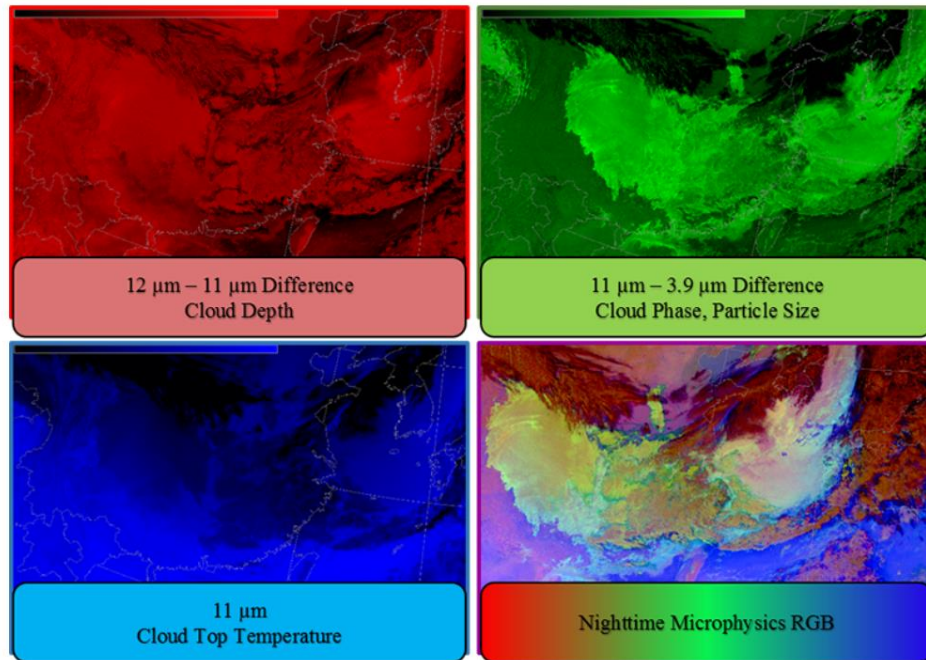


MSG

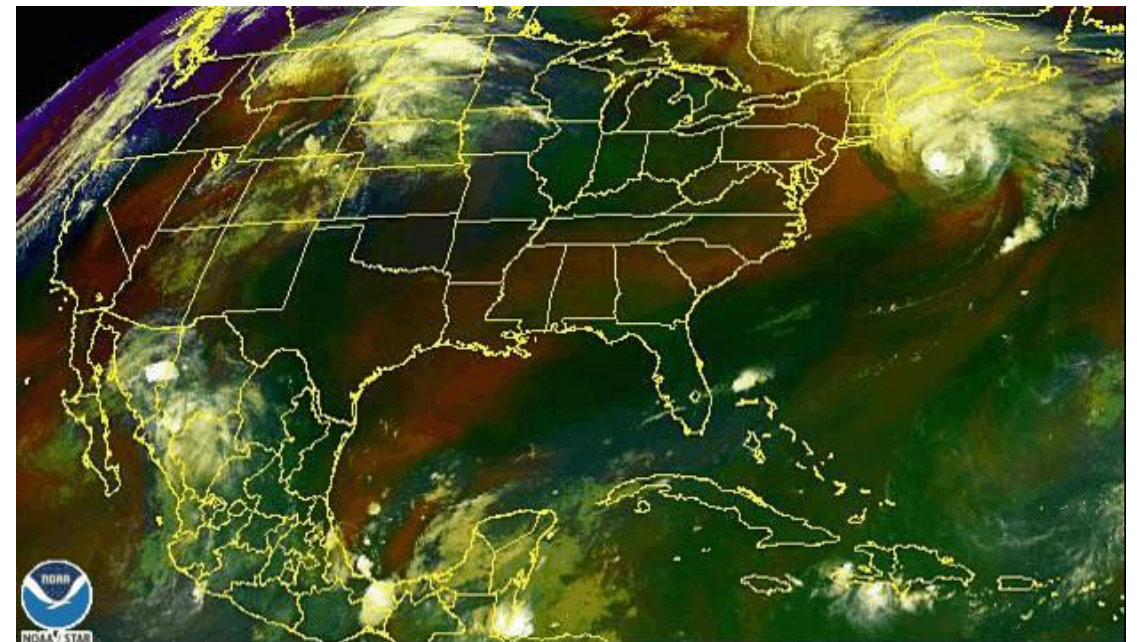


Combining individual channels or channel differences enhances the utility of the individual channel imagery and simplifies qualitative interpretation of weather features.

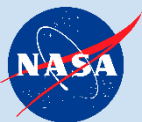
Animation of RGB products from geostationary satellites enhances the understanding of the changing dynamic environment.



Night-time Microphysics RGB



07 Sep 2019 07:21Z NESDIS/STAR GOES-East AirMass



# AM and DWV RGB Composite Products

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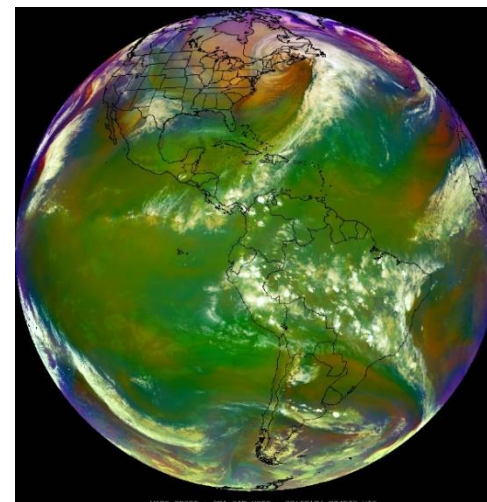
2345 UTC 04 Jan 2018

## Air Mass RGB

Developed by EUMETSAT to evaluate temperature and moisture characteristics of developing synoptic weather systems

Color	Band / Band Diff. (µm)	Min - Max Gamma	Physically Relates to...	*Small input to pixel indicates...	*Large input to pixel indicates...
Red	6.2 - 7.3	-26.2 to 0.6 C 1	Vertical water vapor difference	Moist upper levels	Dry upper levels
Green	9.6 - 10.3	-43.2 to 6.7 C 1	Tropopause height based on ozone	Low trop and high ozone	High trop and low ozone
Blue	6.2 (inverted)	-29.25 to -64.65 C 1	Water vapor ~200-500 mb	Dry upper levels	Moist upper levels

Color	Interpretation
Red	Jet stream; potential vorticity; dry upper levels
Blue	Cold Air Mass
Green	Warm Air Mass
Brown	Warm Air Mass, less moisture
Purple	Limb Effects
Light Green	Warm low-level clouds
Dark Blue	Cold low-level clouds
Orange	Mid-level clouds
White	High, thick clouds



Air Mass RGB

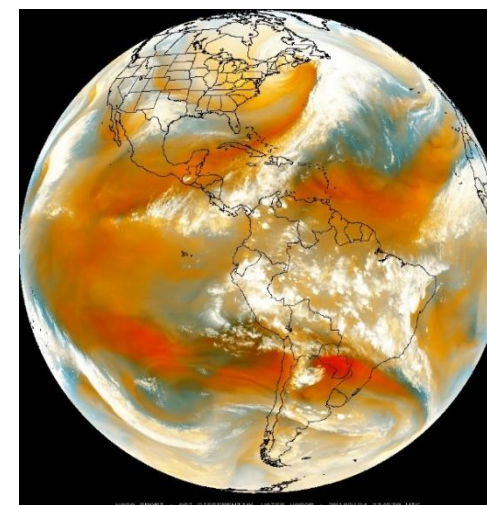
*Composites allow for a quick qualitative assessment of the structure of synoptic weather systems but atmospheric absorption away from satellite sub point creates misleading color variations in the imagery.*

## Differential Water Vapor RGB

Developed by JMA to understand variations in mid-upper level water vapor, horizontal moisture boundaries, trough / ridge patterns

Color	Band / Band Diff. (µm)	Min - Max Gamma	Physically Relates to...	*Small contribution to pixel indicates...	*Large Contribution to pixel indicates...
Red	7.3 - 6.2 (inv)	30 to -3 C 0.2587	Vertical water vapor difference	Moist upper levels	Dry upper levels
Green	7.3 (inv)	5 to -60 C 0.4	Low level water vapor	Dry low levels	Moist lower levels
Blue	6.2 (inv)	-29.25 to -64.65 C 0.4	Upper level water vapor	Dry upper levels	Moist upper levels

Color	Interpretation
Dark Red	Very dry mid-upper level
Orange	Dry mid-upper level
Yellow	Dry mid-upper level; Moist mid level; Mid level cloud
Grey	Moderate moisture mid-upper level
Teal	Moist upper level
White	High, thick clouds



DWV RGB



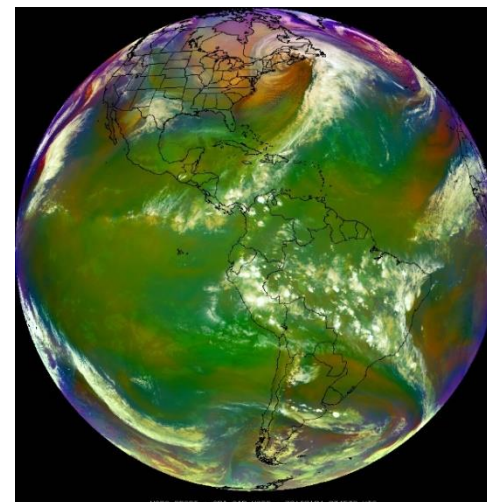
2345 UTC 04 Jan 2018

## Air Mass RGB

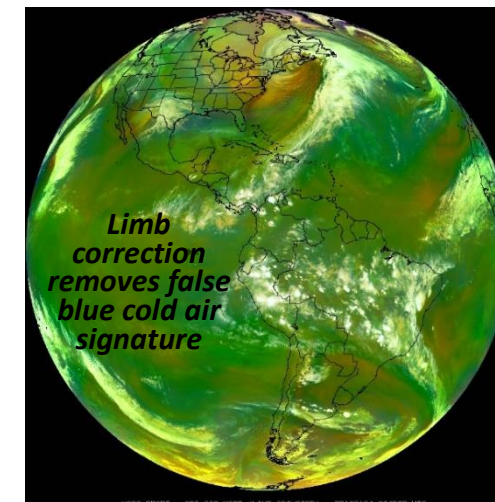
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Air Mass RGB



Limb Corrected Air Mass RGB

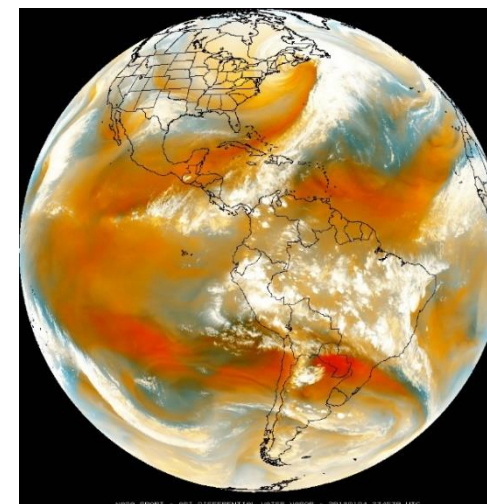
*Limb correction for increased atmospheric water vapor and ozone away from satellite sub-point allows for more accurate imagery for interpretation (Elmer et al., 2019)*

## Differential Water Vapor RGB

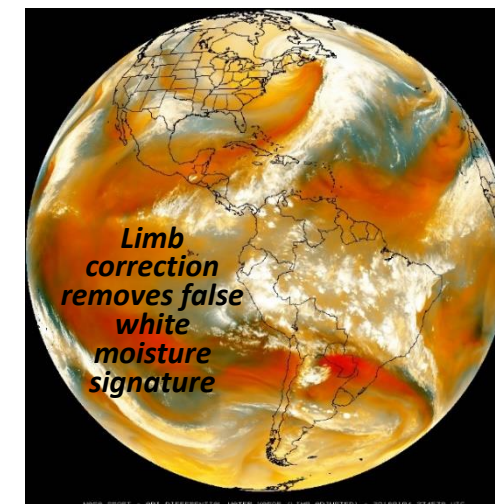
Developed by JMA to understand variations in mid-upper level water vapor, horizontal moisture boundaries, trough / ridge patterns

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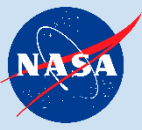


DWV RGB



Limb Corrected DWV RGB

See Elmer et al. (2019)

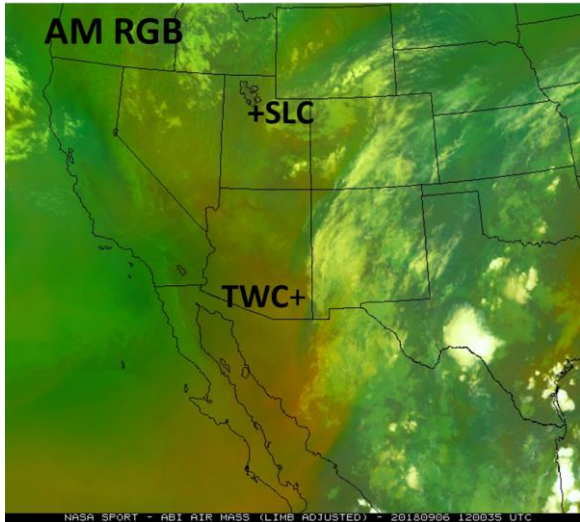


# Application of AM and DWV Composites

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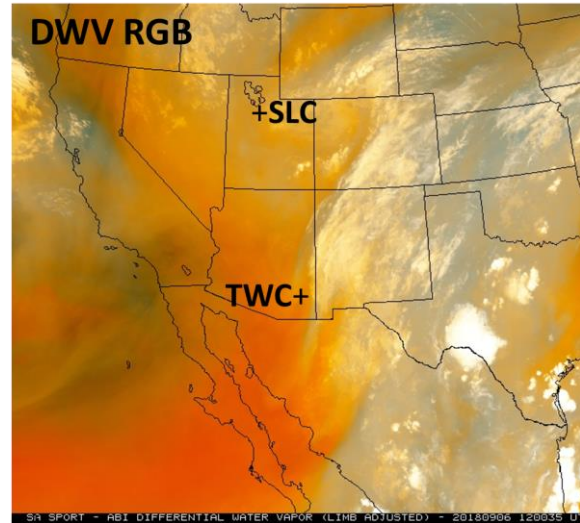
1200UTC 06 September 2018



## AM RGB

Tucson, AZ (TWC): Warm, tropical air mass offshore and inland. More orange tones indicate a decrease in upper-level moisture within the same air mass.

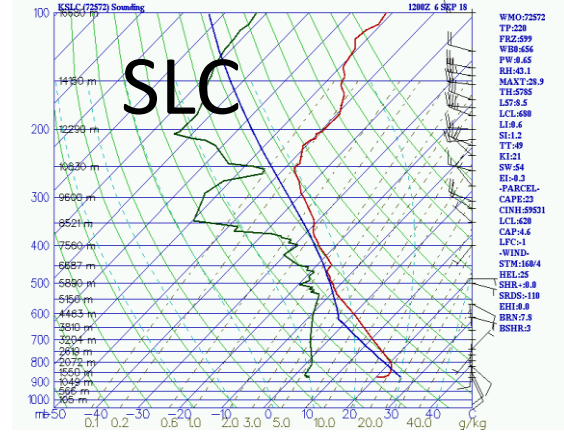
Salt Lake City, UT (SLC): Low to mid level clouds and green tones indicate more low to mid level moisture



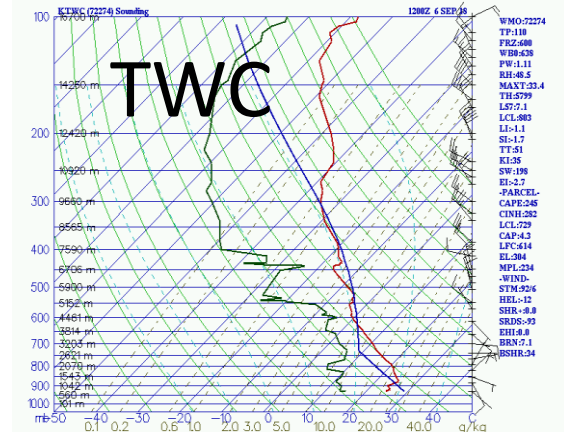
## DWV RGB

Tucson, AZ (TWC): Orange and blue colors offshore indicating upper level moisture over a thick dry layer. Increasing deep layer dryness inland

Salt Lake City, UT (SLC): lighter orange, blue, and gray tones indicate increasing mid to upper level moisture



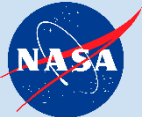
SLC



TWC

TWC sounding confirms the deep layer dryness indicated by the DWV RGB and decrease in moisture in the AM RGB

SLC sounding confirms increasing mid- and upper level moisture

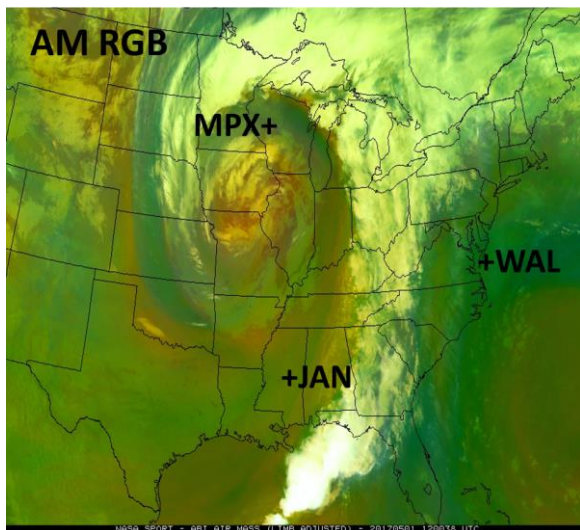


# Application of AM and DWV Composites

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1200UTC 01 May 2018

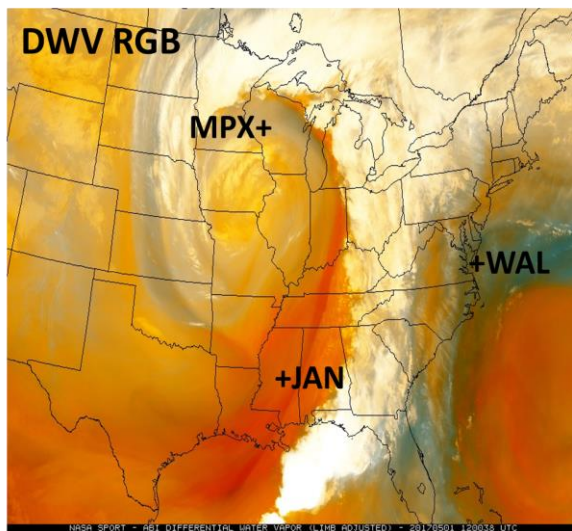


## AM RGB

Jackson, MS (JAN): warm, dry air in olive and orange tones representative of the dry slot

Chanhassen, MN (MPX): increase in upper level moisture in green tones where the dry slot is not influencing the region

Wallops Is, VA (WAL): warm, moist air offshore ahead of the advancing cold front

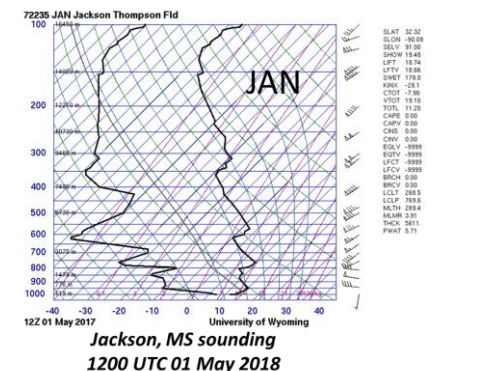


## DWV RGB

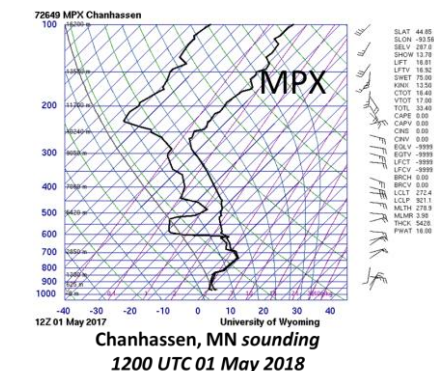
Jackson, MS (JAN): Deep orange tones indicate deep layer dry air verified by JAN sounding

Chanhassen, MN (MPX): increased low to mid level moisture evidenced by the gray color and in MPX sounding

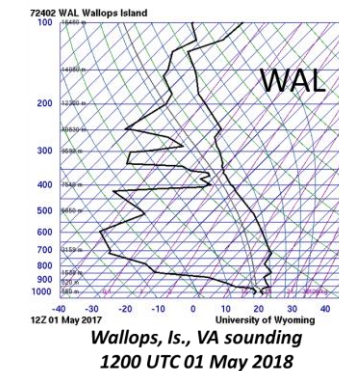
Wallops Is, VA (WAL): bluish-green color indicates moist upper levels with dry air below also seen in WAL sounding



Jackson, MS sounding  
1200 UTC 01 May 2018



Chanhassen, MN sounding  
1200 UTC 01 May 2018



Wallops Is., VA sounding  
1200 UTC 01 May 2018

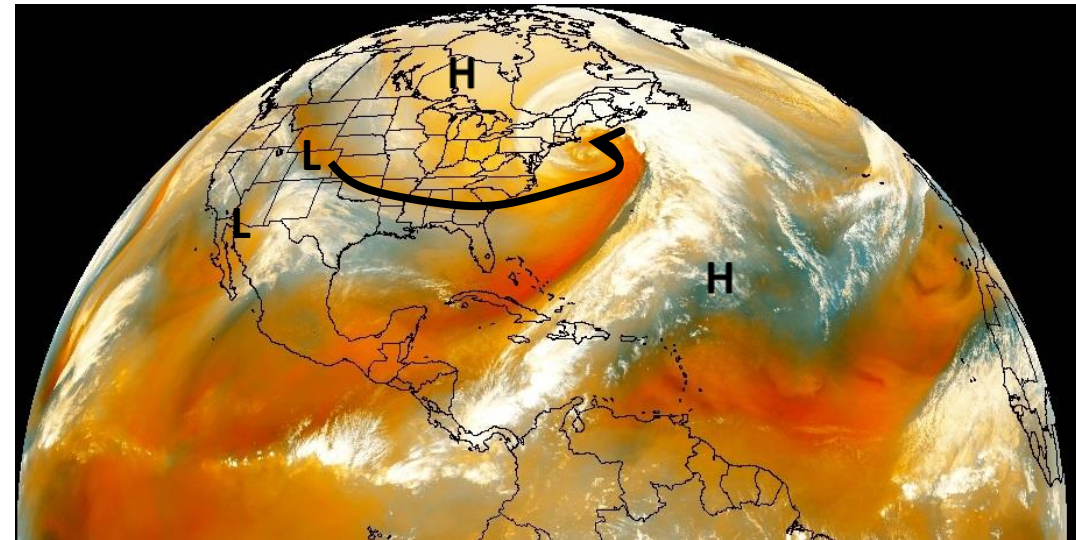
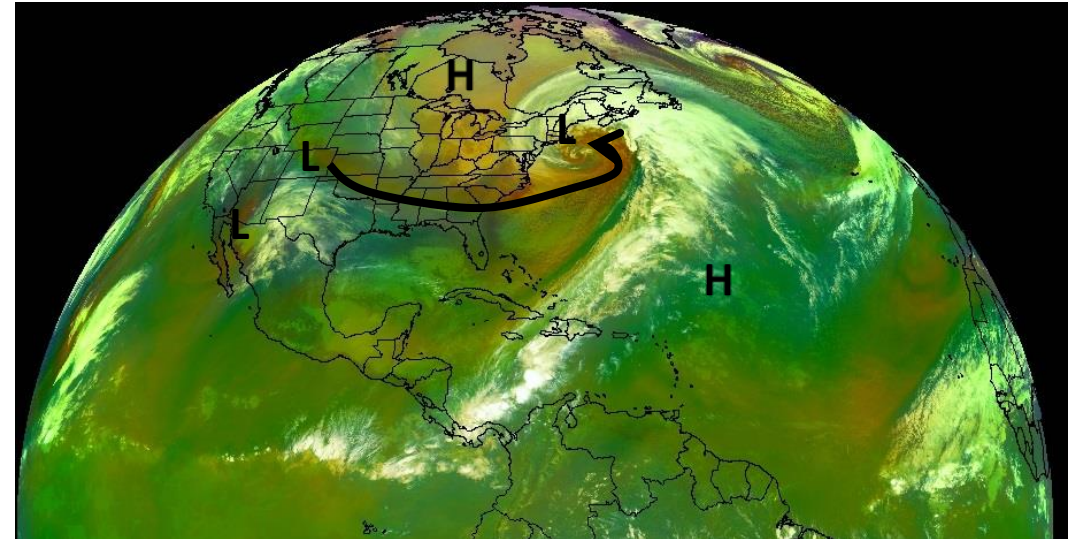


## AM RGB

- Strong high pressure over Atlantic and central Canada with very strong low over New England, weak low over Baja.
- Red-orange colors indicate decreasing upper level moisture, jet stream, and PV anomaly from Midwest into the Low.

## DWV RGB

- Contrasting colors in DWV RGB composite allows for easier interpretation of vertical moisture variability
  - Blue colors associated with Atlantic High indicates dry layer beneath the upper level moisture
  - Lighter orange in western Plains indicative of increased low mid-level moisture
  - Grey colors in advance of clouds in Southwest indicate both mid- upper-level moisture







# Summary and Conclusions

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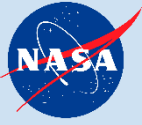
AM and DWV RGB composite imagery highlights 3-D differences in the temperature and moisture structure associated with synoptic weather systems that may otherwise go unnoticed because of the complexity of manually evaluating many individual channels of data.

Important to have guidance on the interpretation of the qualitative RGB imagery. Case study examples and interpretation guidance is useful to gain greater understanding of the utility of these RGB products.

Use of limb-corrected imagery is necessary for interpretation of RGB features located >40% from satellite sub-point.

## RGB imagery comparison

- AM RGB composite highlights variations in tropopause height and upper-level water vapor variability
- DWV RGB highlights additional vertical variability in mid- and upper-tropospheric water vapor structure which may not be apparent in the AM RGB imagery.



# Additional Information / References

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NASA Short-term Prediction Research Transition  
(<https://weather.msfc.nasa.gov/sport>)



Real-time GOES-16 / 17 data  
(<https://weather.msfc.nasa.gov/goes>)



Quick Guides for RGBs  
(<https://nasasporttraining.wordpress.com/quick-guides>)

**Air Mass RGB Quick Guide**

**Why is the Air Mass RGB imagery important?**  
The Air Mass RGB is used to diagnose the environment surrounding synoptic systems by enhancing temperature and moisture characteristics of air masses. Cyclogenesis can be inferred by the identification of warm, dry, clockwise descending stratospheric air associated with jet streams and potential vorticity (PV) anomalies. The RGB can be used to update the location of PV anomalies in model data. Additionally, the RGB can distinguish between polar and tropical air masses, especially along frontal boundaries and identify high-, mid-, and low-level clouds.

Color	Band / Band (nm)	Physically relevant to...	Small contribution to plot features...	Large contribution to plot features...
Red	6.2 - 7.2	Vertical water vapor difference	Moist upper levels	Dry upper levels
Green	8.2 - 10.6	Tropopause height based on cosine	Low tropopause and high cosine	High tropopause and low cosine
Blue	6.2	Water vapor in ~200-500 mb layer	Dry upper levels or warm brightness temperature	Moist upper levels or cold brightness temperature

**Impact on Operations**

**Primary Application:**  
Identifying air masses: polar and tropical air masses and the frontal boundary between them are readily seen in the RGB imagery.  
Inferring cyclogenesis: It is relatively easy to see jet streams and stratospheric air intrusions with high PV, and the cyclonic activity created by these dynamics.  
**Secondary Application:**  
Moisture boundaries, distinguishing between warm air masses with high and relatively low moisture, distinguishing between high clouds and mid-level clouds.

**Limitations**

**Limb effects:** The use of longer wavelength channels results in more atmospheric absorption at large viewing angles. As a result of the greater absorption, cooler brightness temperature are measured. This limb cooling causes false blue and violet colors along the entire limb.  
**Upper Troposphere only:** Conditions in the mid-to-upper troposphere can be detected but surface conditions cannot be directly observed.  
**Cloud cover:** High cloud cover can obscure air masses and make interpretation more difficult.

Elmer, N. J., E. Berndt, G. Jedlovec, and K. Fuell, 2019: Limb correction of geostationary infrared imagery in clear and cloudy regions to improve interpretation of RGB composites for real-time applications. J. Atmos. Ocean. Technol., **36**, 1675-1690.

EUMETSAT User Services, 2009: Best practices for RGB compositing of multi-spectral imagery. Darmstadt, 8 pp. [http://oiswww.eumetsat.int/~idds/html/doc/best\_practices.pdf].

Shimizu, A. and Y. Ioka, 2017: Newly proposed RGBs by Himawari-8 and some case studies. WMO RGB Experts and Developers Workshop, [http://www.wmo.int/pages/prog/sat/meetings/RGB-WS-2017.php]

**Air Mass RGB Quick Guide**

**RGB Interpretation**

1. Jet streams / PV / Stratospheric air / dry upper levels (dark red/orange)
2. Cold air mass (dark blue/purple)
3. Warm air mass (red)
4. Warm air mass, low moisture (dull green)
5. High thick cloud (white)
6. Mid-level cloud (pink/purple)
7. Low-level cloud (green, dull blue)
8. Limb effects (purple/blue)

**Usage with other products:**  
The 6.2 µm water vapor channel (red) can be useful to observe air mass interactions, jet streams, and deformation zones. The 10.6 µm channel from the same time as the RGB above, the PV anomaly is apparent, but air mass temps and moisture are not.

**Resources**

- UMC/COMET Multi-spectral Satellite Applications RGB Products Explained
- NASA/SPORT Analysis Explains the RGB Products
- EUMETSAT RGB Interpretation Guide